Random Scrambling and Running Addition of PCA coefficients for Cancelable biometrics

MinYi Jeong, Jeung-Yoon Choi and Jaihie Kim
Biometrics Engineering Research Center (BERC)
School of Electrical and Electronic Engineering
Yonsei University, Republic of Korea
E-mail: myjeong@yonsei.ac.kr

Abstract: In terms of user authentication, biometric systems offer numerous advantages in terms of convenience. However, they also suffer from disadvantages in some applications, for example, in the area of privacy protection. To enhance security and privacy in biometrics, cancelable biometrics have been introduced. In this paper, we propose cancelable biometrics for face recognition using a PCA method approach. In the proposed method, our experiment compares the performance between the cases where PCA coefficient vectors, and the transformed coefficient vectors are respectively used for verification. As a result, the proposed method satisfies a good level of condition for cancelable biometrics. The proposed method not only resolves a weak point of biometric systems, but also the method is simple.

1. Introduction

Biometrics [1] is a method of personal authentication. Among its advantages is the fact that information cannot be stolen, forgotten, or shared. However, there are also weak points. One of these problems is the issue of privacy concerning non-revocable biometrics, especially in the case of identity theft.

Cancelable biometrics [2] offers an alternative to these problems. These systems consist of an intentional, repeatable distortion of a biometric signal based on a chosen transform. The biometric signal is then changed in the same way at each presentation, for enrollment and for every authentication. With this approach, every instance of enrollment can use a different transform, so that cross-matching is impossible. Furthermore, if one variant of the transformed biometric data is compromised, then the transform function can simply be changed to create a new variant for re-enrollment.

For cancelable biometric systems, there are four points to be considered [3]. The first point is that even if the biometric features are known, the original biometrics cannot be recovered. This is called non-invertibility. Functions that change the template have to be non-invertible transformations. The second, changeability, refers to the degree of deformation for transformed data as compared to the original data or the new transformed data. If the transformed data is very different from the original information, it is considered to be better privacy-protected. And if newly transformed data is different from previously transformed information, it is considered to be better system-protected. The third point is that transform functions can be created indefinitely. That is, the number of possible changed templates must be either unlimited or numerous. This property is called reproducibility. The last is that after transformation, the recognition rate must not be much lower than the original recognition rate.

Several methods have been developed concerning cancelable biometrics using fingerprint [4-6] or face [3, 7-15] data. In this paper, we propose a method for generating cancelable biometrics derived from face images.

To describe the method proposed here, the organization of this paper is as follows. In section 2, we describe the proposed method for cancelable face biometrics. In Section 3, the proposed method is evaluated with respect to performance accuracy. Finally, concluding remarks are presented in Section 4.

2. Cancelable Biometrics for PCA coefficient Based Face Data

2. 1 PCA

Some typical algorithms for face recognition are appearance based and model-based approaches. Appearance-based techniques have been widely used in face recognition research. Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Nonnegative Matrix Factorization (NMF) are representative techniques for appearance-based face recognition. In our method, the PCA method was adopted for its widespread use in face recognition authentication systems. PCA is a method which efficiently represents a collection of sample data.

Matthew A. Turk [16, 17] published a face recognition scheme that used eigenfaces. PCA is a way of identifying patterns, and expressing the identified information to highlight similarities and differences. The eigenface algorithm uses PCA for dimensionality reduction in order to identify the vectors which best account for the distribution of face images within the entire image space. These vectors define the subspace of the face images. This subspace is also called the face space. This is a method which efficiently represents a collection of sample information.

2. 2 Cancelable Face Biometrics Using Random Scrambling and Running Addition

The main idea of the proposed method is to generate transformed coefficient vectors by addition from the scrambled PCA coefficient vectors. In this paper we used PCA, but other appearance based methods such as ICA [11] and NMF can be applied in the same way. Fig. 1 shows the block diagram of the face recognition system using the proposed method.

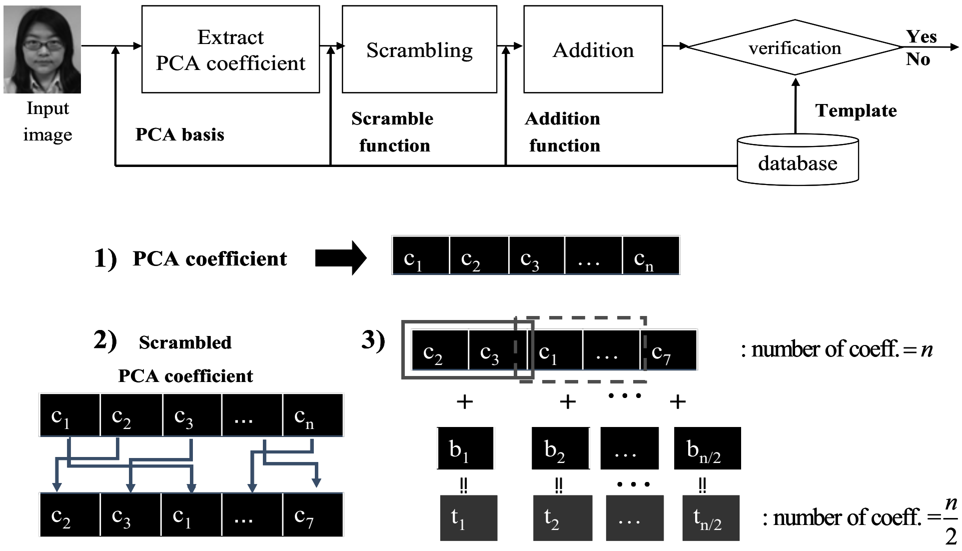


Fig. 1 Block diagram and illustration of the proposed method.

First, PCA coefficient vectors $\mathbf{P} = [c_1, c_2, \cdots, c_n]$ were extracted from an input face image. Here, $\mathbf{P}$ is a PCA coefficient matrix and $c_1, c_2, \cdots, c_n$ are PCA coefficient vectors of a PCA basis in the database.

To increase reproducibility and heighten changeability, we can apply scrambling to components of the PCA coefficients. Scrambling increases the reproducibility of changeable biometrics, because the order of components for each PCA vector can be scrambled differently. The scrambled PCA coefficient vectors are given by $\mathbf{P}_s = S(\mathbf{P}) = [s_1, s_2, \cdots, s_n]$, where randomly chosen columns interchanged. Namely, it is defined from a scrambling function $\mathrm{S}(\bullet)$. $\mathrm{S}(\bullet)$ is a function for scrambling the PCA coefficient vector $\mathbf{P}$ and $\mathbf{P}_s$ is the scrambled PCA coefficient vector matrix. The $s_1, s_2, \cdots, s_n$ are the re-ordered PCA coefficient vectors.

When the transformed coefficient vector by re-ordering is found to be compromised, new transformed coefficient vectors can be generated by new scrambling rules. In this way, many transformed face coefficient vectors can be easily generated.

Finally, the cancelable face template is generated by addition from two scrambled PCA coefficient vectors as follows:

$$\mathbf{T} = \text{running\_sum}(\mathbf{P}_{\mathrm{s}}) = \text{running\_sum}(S(\mathbf{P})) \quad (1)$$

$$\mathbf{T} = \text{running\_sum}(\mathbf{P}_{\mathrm{s}}) = \text{running\_sum}(S(\mathbf{P})) = \sum_{\mathrm{m=1}}^{\mathrm{n-1}} [\mathrm{s_m} + \mathrm{s_{m+1}}] \quad (2)$$

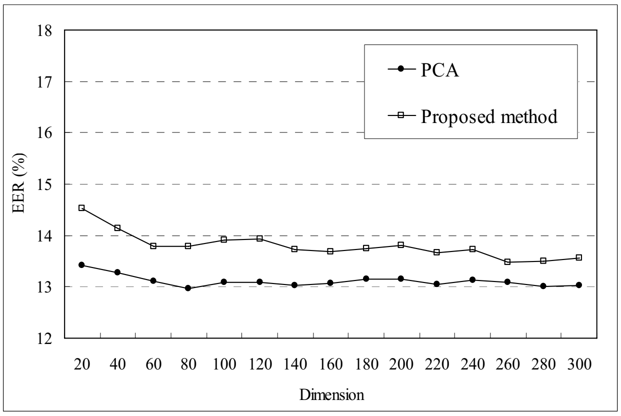
One of the conditions for cancelable biometrics is that transformed biometric data should not be easily converted back to the original biometric data even if an attacker knows both the transformed biometric data and the transforming method. Even if an attacker can find the cancelable face template T and the scrambling function S, it is impossible to recover the original face data (PCA coefficient vector) from the cancelable face template (transformed coefficient vector). Therefore, the proposed method satisfies the property of non-invertibility.

3. Experiments

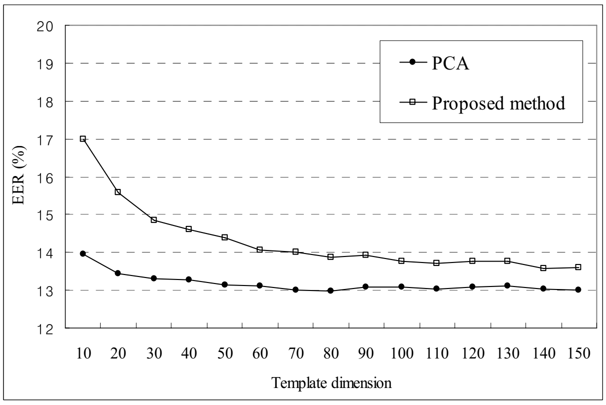
In this section, experimental analysis is performed relative to performance. In this paper, we examined how the recognition rate varies when the number of dimensions is changed from 300 to 10 and when the number of template coefficient is changed from 150 to 10.

We used a MPEG-7 face database [18]. This database includes faces with different facial expressions and illumination directions, for a total of 500 images. Each image in the MPEG-7 face database consists of a 46 by 56 array of pixels. The training set contains a single image for each of the 50 subjects. The images of the remaining 50 subjects were used as the test set. Fig. 2 shows some sample images taken from the database.

Fig. 2 MPEG-7 face database



(a)



(b)

Fig. 3 Accuracy performance (EER) of PCA and the proposed method as (a) dimensions, (b) templates varies

We used the Equal Error Rate (EER) for accuracy performance and the Euclidian distance for a dissimilarity measurement.

The experimental results of the proposed method must be found for multiple instances for each simulation because the transformed face template is generated by a randomly changing scrambling function. Therefore we carried out a total of 50 experiments and averaged the results for an average EER.

Fig. 3 shows EER results when the PCA coefficient vector is used for verification, and when the cancelable face template is used for verification, as the number of extracted coefficient dimension varies (a) and as the number of database templates varies (b). The experimental results show that EER of the proposed method was degraded about 0.69% (min was 0.38%, max was 1.11%) for varying dimensions. And the EER was degraded about 1.12% (min was 0.53%, max was 3.05%) when the number of templates varies. Both results do not degrade significantly over using conventional PCA based methods.

4. Conclusion

Cancelable biometrics uses transformed or distorted biometric data instead of original biometric data for identifying a person. When a set of biometric data is found to be compromised, it can be discarded and a new set can be generated. In this paper, we proposed a cancelable biometric system for face recognition using PCA method based approach. The main idea was to scramble the PCA component of coefficient vectors and add resulting scrambled coefficient vectors. This transformed vector is used for new face recognition templates. By scrambling the order of the coefficients in the transform function, we were able to generate numerous instances of cancelable face templates. Moreover, this method is non-invertible. Therefore the proposed method resolves a weak point of biometric systems. However, from experimental results, it is shown that this method does degrade performance compared to that of conventional methods. For future work, we plan to conduct a study for improving performance accuracy and analysis of essential conditions for cancelable biometrics.

Acknowledgments

This work was supported by the Korea Science and Engineering Foundation (KOSEF) through the Biometrics Engineering Research Center (BERC) at Yonsei University. R112002105080020(2008)

References

[1] A. Pankanti, R.M. Bolle, and A.K. Jain. Biometrics: the future of identification, IEEE Computer, Vol. 33, No. 2, pp.46-49, 2000.

[2] N.K. Ratha, J.H. Connell, and R.M. Bolle, "Enhancing security and privacy in biometrics-based authentication systems," IBM Systems Journal, Vol. 40, No. 3, 2001.

[3] M.Y. Jeong, C. Lee, J. Kim, J.Y. Choi, K.A. Toh, and J. Kim, "Cancelable Biometrics for Appearance based Face Recognition," Proc. of Biometrics consortium conference, September 2006.

[4] R. Ang, R. Safavi-Naini, and L. McAven, "Cancelable Key-Based Fingerprint Templates," 10th Australasian Conference on Information Security and Privacy, pp. 242-252, 2005.

[5] N. Ratha, J. Connell, R. Bolle, and S. Chikkerur, "Cancelable Biometrics: A Case Study in Fingerprints," ICPR, Vol. 4, pp. 370-373, Aug. 2006.

[6] C. Lee, J. Choi, K. Toh, S. Lee, and J. Kim, "Alignment-Free Cancelable Fingerprint Templates Based on Local Minutiae Information," IEEE Transactions on Systems, Man and Cybernetics - Part B, Special Issue on Recent Advances in Biometrics Systems, October, 2007.

[7] M. Savvides, B.V.K Vijaya Kumar, P.K. Khosla, "Cancelable Biometric Filters for Face Recognition", Proceedings of the 17th International Conference on Pattern Recognition (ICPR 2004), 3, pp. 922-925, 2004.

[8] A.B.J. Teoh, D.C.L. Ngo, and A. Goh, "Personalised cryptographic key generation based on FaceHashing", Computers and Security, Vol. 23, No. 7, pp. 606-614, 2004.

[9] A.B.J. Teoh, and D.C.L. Ngo, "Cancellable biometrics featuring with tokenized random number", Pattern Recognition Letter, Vol. 26, No. 10, pp. 1454–1460, 2005.

[10] J. Kang, D. Nyang, and K. Lee, “Two Factor Face Authentication Scheme with Cancelable Feature”, International Workshop on Biometric Recognition Systems (IWBRS), pp. 67-76, 2005.
[11] M.Y. Jeong, C. Lee, J.Y. Choi, and J. Kim, “Changeable Biometrics for PCA based Face recognition,” IEEK summer conference, vol. 29, no. 1, pp. 331-332, 2006.
[12] T. Boult. “Robust Distance Measures for Face-recognition supporting revocable biometrics token,” 7th International Conference Automatic Face and Gesture Recognition, Southampton, UK, April 10-12, 2007.
[13] M.Y. Jeong and J. Kim, “A Study of Generation for Changeable Face Template,” IEEK summer conference, vol. 30, no. 1, pp. 391-392, 2007.
[14] M.Y. Jeong, C. Lee, J.Y. Choi, and J. Kim, “Generation of Changeable Face Template by Combining Independent Component Analysis Coefficients,” Journal of IEEK, vol. 44-SP, no. 6, pp. 16-23, 2007.
[15] M.Y. Jeong, J.Y. Choi, and J. Kim. “Using Genetic Algorithms to Improve Matching Performance of Changeable biometrics from Combining PCA and ICA Methods”, Computer Vision and Pattern Recognition (CVPR), Jun 2007
[16] M. A. Turk and A. P, “Pentland. Eigenfaces for recognition”, Cognitive Neuroscience, vol. 3, no. 1, pp. 71-86, 1991.
[17] M. A. Turk and A. P. Pentland, “Face Recognition Using Eigenfaces,” Computer Vision and Pattern Recognition, 1991, Proceedings CVPR ’91, IEEE Computer Society Conference on 3-6, pp. 586-591, 1991.
[18] H. Kim, D. Kim, S. Bang, “A PCA Mixure model with an Ecient Model Selection Method”, Proceed-ings IJCNN 2001, 2001.